Bulletin No. 42.
W. B. 467.

Issued March 5, 1913.

U. S. DEPARTMENT OF AGRICULTURE,

WEATHER BUREAU.

FORECASTING THE WEATHER.

Prepared under the direction of WILLIS L. MOORE, Chief U. S. Weather Bureau,

BY

GEORGE S. BLISS,

SECTION DIRECTOR.

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PREFACE.

In this bulletin the precise style of the textbook is purposely avoided, the object being to present some of the generally accepted facts and theories of meteorology in an elementary form and in a comparatively inexpensive publication to permit of a wide circulation.

No pretense is made of advancing new theories or ideas, except the one of popular education along these lines.

The basic matter, as taught by Profs. Moore, Davis, Hann, Mill, and other recognized authorities, has been clothed in the author's own verbiage. Technical terms have been avoided so far as consistent, and the work has been made elementary to the extent of adopting the form of direct address, in some instances, as being most impressive and effective.

The subject matter was, in the main, first published as a series of newspaper articles, and has since been revised to its present form by direction of Chief of Weather Bureau to meet the numerous demands that followed its first publication.

In the revision the author was materially assisted by suggestions from Mr. Edward L. Wells, Mr. Roscoe Nunn, and Profs. Alexander McAdie and J. Warren Smith.

THE AUTHOR.

CONTENTS.

FORECASTING THE WEATHER.

I. Introductory.

If it were possible for a certain man to rise to a point every 12 hours where he could view the entire country from the Atlantic to the Pacific, from Canada to Mexico and the West India Islands, and if he could distinctly see the weather conditions over that entire territory and could watch the developments and movements of the storm areas, you would no doubt have a great deal of confidence in his ability to give out information regarding those conditions.

If on descending from one of his observations he should state that a storm area was moving in such a manner that its edge would pass near a given locality, you could readily understand that it would be a difficult matter to determine with certainty whether it would touch that particular locality or not.

Under such circumstances you would not call him a guesser if he should be in error 20 per cent of the time. You would say, "That man goes up where he can see all of the storms every 12 hours and can trace their movements continuously. He is able to outline ahead of each storm the greater portion of the territory that it will cover during the succeeding 24 to 36 hours. When the movements are somewhat irregular and the storms extend slightly beyond the territory outlined in some places and do not quite cover it in other places, it is a result that might reasonably be expected. On the average his information is accurate for more than four-fifths of the territory outlined, and such a high degree of success is surely not to be termed guesswork. If he can not tell with certainty regarding some localities then there is no use in others trying to do so, for he sees it all."

If any man could accomplish such a survey, what would his services be worth to the country? What would you think of the person who attempted to belittle his advice? Wouldn't it be plain to you that after obtaining a bird's-eye view of the whole country he would, at once, know more about the prevailing conditions than anyone else possibly could? Wouldn't you have a great deal of confidence in the opinions and advice that such a man offered, and wouldn't you defend him against all unjust criticism?

Difficult as such an achievement seems at first thought, the fact is that our Government maintains a weather service based on those same principles. The Weather Bureau of the United States Department

of Agriculture not only obtains, as it were, a bird's-eye view of atmospheric conditions over the entire country every 12 hours, but on special occasions it makes a survey of a severe storm area every 3 or 4 hours, following its movements and developments very closely until it spends its force or passes beyond the limits of observation.

When reading the forecasts and warnings issued by the Weather Bureau from time to time, you may not have realized that they were based upon such an elaborate system. Possibly you have been inclined to give equal confidence and credit to the opinions of certain individuals who talk mysteriously about the influence of the moon and the planets upon our weather, and who attempt to create the impression that the scientists of our Government Weather Bureau are groping in the darkness of ignorance.

It is the purpose of this pamphlet to explain how the seemingly impossible feat of obtaining an atmospheric survey of the entire country is accomplished, and to show that it is the only logical means of forecasting the weather. The following articles will also explain how the various phenomena that we experience in our daily weather changes are accomplished by physical forces in our atmosphere, and in a general way are well understood:

II. How it is Done.

Of course it is impossible for anyone to attain an elevation from which to view the whole country at once, but equivalent results are obtained by another process.

The Weather Bureau maintains telegraphic observing stations in all parts of the country, there being something over 200 of them in all; and observers at these numerous viewpoints, all acting simultaneously, are able to accomplish just as satisfactory a survey as would be obtained by one person at a single viewpoint if such a thing were possible.

Every 12 hours, precisely at 7.45 a. m. and 7.45 p. m., seventy-fifth meridian time, the observers in all parts of the country begin the work of observing and recording the weather conditions, each in his respective territory. The sky is observed and the clouds are classified; the barometer is read and corrections are applied to obtain the corresponding reading for sea level, so that all barometers may show the value for the same plane; the direction and the velocity of the wind are noted; the rainfall or snowfall, if any, is measured; the current temperature and the extremes since the last previous observation are taken from the several thermometers; the moisture content of the atmosphere is calculated; and all other phenomena, such as thunderstorms, fog, smoke, halos, etc., are carefully noted. Each observer then condenses the information he has secured into

a telegraphic cipher message of 4 or 5 words, that when translated or expanded into descriptive language would comprise from 30 to 50 words. This work consumes about 15 minutes, and is completed at all stations by 8 o'clock.

The messages are rapidly transmitted to main line telegraphic circuits, and are collected at the central office in Washington, and are also interchanged between many of the larger cities where forecasters are stationed. At these various centers, the messages are translated as fast as they are received, and the conditions are inscribed in their respective places on an outline base map of the country by means of figures, letters, and symbols.

The locations of the observing stations are indicated by small circles. Where cloudiness prevails the whole area of the circle is blackened; for partly cloudy conditions one-half of the circle is blackened; while the whole is left clear to represent clear skies. If rain is falling at the time of observation an "R" is marked in the circle, or an "S" for snow, as the case may be. Arrows are inscribed to fly with the wind. The barometer reading, temperature, wind velocity in miles per hour, and the depth of precipitation (rain or snow), if any, are written by the side of each station in figures. The precipitation areas are outlined and shaded. Red lines are drawn through points of equal barometric readings, and indicate atmospheric disturbances, the significance of which will be explained in later chapters. Blue lines are drawn through points of equal temperature, and the completed chart is known as a weather map.

The work, from observations to map making, is all conducted under such specific rules and regulations that the finished map is as complete a bird's-eye view for the experienced forecaster as if he had beheld all the conditions with his own eyes.

In less than 2 hours from the time the observations are taken, the various forecasters are, figuratively speaking, standing on eminences overlooking the entire country, and are prepared to give out information regarding the weather conditions in any section as well as to forecast the probable developments for a day or two in advance. By means of the map, the forecaster is enabled to anticipate the conditions for another State or for a distant city with nearly as high a degree of accuracy as he can for his own locality.

It should be borne in mind that the information that the forecaster gives out regarding the conditions in any portion of the country is derived from the reports of actual observations and is distinctly accurate and reliable. The forecasts that he issues represent his conclusions regarding the probable movements and developments for the time specified, but human judgment must necessarily contain some element of error.

However, as in the supposed case of the man with the bird's-eye view, we must conclude that if the forecaster with so much information before him can not always anticipate the movements and developments accurately, it would be useless for one not so equipped to attempt to excel him.

III. A Short Study of a Weather Map.

If you have never studied the weather maps, but have merely glanced at them occasionally, thinking them to be only picture puzzles in which the lines are hopeless tangles and the figures and symbols represent nothing in particular, it will be interesting at this time to analyze a map and consider its prominent features.

At the end of this chapter is a map, selected because of its near approach to a theoretically ideal type that would well illustrate the general laws applicable to our atmospheric disturbances.

The isobars, or lines of equal barometer readings, form the most prominent feature of the map, as they locate the great centers of action. They are drawn for each tenth of an inch of variation. For example, the line marked "30.0" at each end passes through points where the barometer readings are just 30 inches. On one side of this line the readings are higher than 30 inches, and lines are drawn for each tenth of an inch increase until a center or crest is located and marked "High." On the other side lines are drawn for each tenth of an inch decrease until the center of the depression is located and marked "Low."

The real significance of barometer readings will be more fully explained in a chapter on "Atmospheric pressure," but for the present it will be sufficient to note that the isobars outline great atmospheric whirls or eddies.

Bearing in mind that the arrows are inscribed to fly with the wind, a careful inspection of the area having "Low" at the center will reveal the fact that the winds blow in toward the center, not directly, but spirally, just as water in passing down through a funnel flows around the center and approaches it gradually. You will further observe that the winds rotate about the center in a direction against the hands of a watch, face upward. Some places will be noted where the winds do not conform to the above rules, being temporarily deflected by local conditions. The more intense and energetic the disturbance becomes the more nearly will the wind movements conform to the general laws, as the forces in the great atmospheric eddy become strong enough to overcome local influences.

Now, if you will examine the area marked "High" at the center you will observe that the winds move in opposite directions from those in the "Low." In other words, they blow spirally outward

from the center. Also it will be noticed that the air currents flow in a compound curve from the center of the "High" toward the center of the "Low."

Since the surface winds, as indicated by the arrows, blow in toward the center of the "Low" from all directions, it becomes apparent at once that the air rises in the central area. Conversely, it is equally evident that the air is constantly settling down in the central area of the "High." The fact that the surface air currents flow from the center of the "High" toward the center of the "Low" suggests the idea that at some distance above the earth the rising air in the "Low" must flow toward the "High," and such indeed is the case.

It must not be imagined, however, that the interchange of air as noted above comprises the complete circulation of these areas, for if we were to map a larger territory we would discover adjacent disturbances with which the same relations are maintained.

The temperature conditions attending this atmospheric circulation are very interesting. Note that the freezing line (drawn through points having a temperature of 32° F.) begins in the extreme northeast, in central New Brunswick, and extends nearly due westward to a point north of the center of the "Low," and thence it sweeps southward nearly to the Texas coast, then northwestward into southern California, whence it bears northward nearly parallel to the Pacific coast line. A study of the wind directions with relation to this line will suggest some of the reasons for its trend.

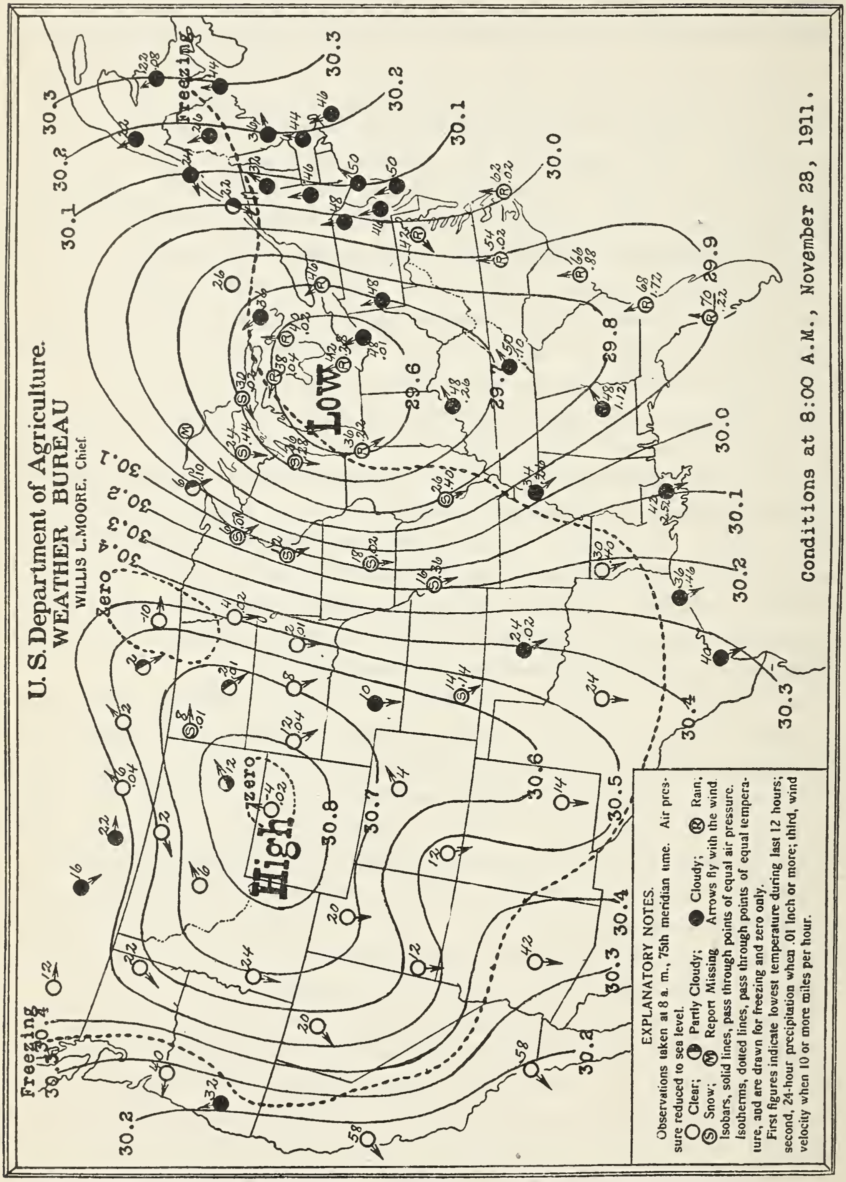
The weather conditions in these large atmospheric whirls are as remarkable as are the temperature conditions. Observe the prevailing cloudiness in the low-pressure area, bearing in mind that it is cloudy at the places marked with an "R" or an "S" the same as where the circles on the map are blackened. By way of contrast notice the clear skies over the greater portion of the high-pressure area.

Areas of high and low barometric pressure are constantly and successively drifting across the country from the west toward the east, and with the foregoing explanations the reader can readily understand the causes of our weather changes.

It becomes evident that while an area of low barometric pressure is drifting over a given locality the weather will ordinarily be cloudy, with a tendency to rain or snow, depending on the season of the year. The temperature will at first be comparatively high, followed by colder when the center of the area has passed and the wind shifts to a westerly or northwesterly direction. As the area of low pressure passes eastward and is succeeded by an area of high pressure, the temperature will continue to fall for a time and the skies will clear.

A rapid succession of high and low pressure areas implies frequent changes in weather and temperature conditions, while conversely

a sluggishness in the movements of these areas tends toward a prolongation of given types of weather.



IV. The Contrast.

Thus far we have dwelt upon the similarity between the Weather Bureau map and a bird's-eye view of the country. Let us now contrast them and consider the numerous advantages that favor the map.

The person with a bird's-eye view could note the areas of cloudiness and sunshine, as we find them plotted on the weather map. He would necessarily be above the clouds and could not see where rain or snow was falling. Granting, however, that the types of clouds might enable him to closely approximate the precipitation areas, he would still be unable to determine the intensity or severity by measuring the amount of rain or snow fall. The Weather Bureau map gives all of this information accurately.

The bird's-eye view would enable the observer to determine the directions of the surface winds and to approximate their velocity in the clear areas by watching the drift of smoke, but in the cloudy areas he could only watch the cloud movements and estimate the surface winds from a general knowledge of atmospheric circulation. In high winds and gales he might catch occasional glimpses of heavy seas and of the destruction on land, but most of these effects would be obscured by intervening storm clouds. The observers of the Weather Bureau can see the cloud movements above and the effects of the storm underneath, and in addition they are enabled to measure the velocity of the surface winds.

The observer aloft could gain very little knowledge of the temperature. Under certain conditions he might see evidences of unusual extremes, but his knowledge would be crude and only approximate at the best. By means of the Weather Bureau map we may know exactly the temperature conditions in all parts of the country, and by comparison with previous maps we can see where they are rising and where they are falling. By taking a pencil and outlining the districts where the temperatures are rising and where they are falling, and then comparing maps, we can watch the movements of the warm and cold areas across the country just as clearly as we can that of the rain areas. By considering the amount of change that is taking place in any area, we can forecast for localities ahead of it as to whether the temperature change will be up or down and much or little.

A greater advantage than any or possibly all of those mentioned in favor of the weather map is the fact that it gives the barometer readings, thus accurately outlining the great atmospheric whirls or eddies and showing the slightest increase or decrease in energy. The man with the bird's-eye view could only approximate the territory covered by these disturbances, by means of noting the wind directions and the distribution of cloudiness, as explained in the preceding chapter. He could not detect moderate changes in energy or intensity.

Thus the observations, which are taken regularly every 12 hours by the Weather Bureau, are not only comprehensive bird's-eye views, but, more than that, they are complete and accurate surveys

of all the atmospheric conditions. When one comes to fully understand what the weather map represents, it takes on a new significance and an added importance. It is seen that the impossible bird's-eye view, as proposed in the first chapter, could not accomplish so much after all, and the private theories of the village weather prophet, which formerly seemed so plausible, become equally vaporous.

The distinctly practical and scientific methods of the Weather Bureau have no doubt appealed to the reader, but before making a closer analysis of the maps for the purpose of explaining more of the principles of forecasting, it will be advisable to study some of the more important characteristics of our atmosphere.

V. The Atmosphere.

The atmosphere is composed of a mixture of gases and surrounds or envelops the whole earth. It is sometimes likened to a great sea of gases, at the bottom of which we live without the power to rise to the surface. The principal constituents are oxygen and nitrogen, in about the proportion of 21 per cent of the former and 78 per cent of the latter, the remaining 1 per cent being made up of five other gases. Water vapor, which is really water in a gaseous form, is always present but is a variable quantity. It occupies space independent of the other gases, and may comprise from 1 to 5 per cent of the total weight of a given volume of air.

The tendency for these gases to escape into space is overcome by the earth's attraction, and they rest upon its surface with about the same weight as a layer of water 34 feet in depth. In other words they press downward, and obeying the law of gases they also press in every other direction at sea level at the rate of nearly 15 pounds per square inch of surface.

We can not see the gases, and since they permeate all our tissues we do not feel their pressure except when they are in motion as wind. It used to be supposed that the atmosphere had no weight, and hence the saying "light as air."

Since the density of air at sea level is only about one eight-hundredth part that of water, it follows that the atmosphere would be eight hundred times 34 feet, or about 5 miles in depth if it were of the same density at all altitudes, which it is not. Gases are easily compressed, and therefore the layers near sea level have the greatest density because they are compressed by the weight of all that lies above. With increase of distance above sea level this weight is decreased steadily by the amount of air that is left below, and thus the pressure and density gradually diminish to nothingness.

So much of the atmosphere is compressed into the lower layers that one-half of it lies below an elevation of 3½ miles, although traces of its lighter gases have been revealed at an altitude of nearly 200

miles. Only one sixty-fourth of the atmosphere lies above an altitude of 21 miles, so we may realize that this gaseous envelope is relatively very thin as compared with the diameter of the earth.

The gases of the atmosphere are not in chemical combination, but are only mixed together, and according to Dalton's law each of them occupies space independent of the others. The lighter gases have the greater depth, and it is believed that hydrogen overcomes the earth's attraction and escapes into space. Nitrogen, which is the lightest atmospheric gas except hydrogen, is retained by the earth's attraction and forms what may be termed the outer limits of the atmosphere. Oxygen extends about four-fifths as high as the nitrogen, while water vapor and the heavier gases such as argon and carbon dioxide become very rare at the elevation of our highest mountain peaks.

The air holds in suspension many substances, such as bacteria and dust particles. We may sometimes think that it would be a great advantage to have all such foreign matter eliminated, but if so it is because we do not fully realize what the results would be.

Only a small portion of the bacteria are of the disease-breeding types, while many of the remainder are of real benefit to mankind. Bacteria are the chief factors in manufacturing all of the products of fermentation, and also they are the active agents that disintegrate the organic matters in the soil and prepare them for plant food.

The inanimate dust particles in the air are very important as they diffuse the sunlight and thus give a uniform illumination to the atmosphere. If the air were entirely freed from the dust and vapor particles, there would be a maximum of bright light and dense shadows.

VI. Heating and Cooling of the Atmosphere.

In this short treatise of the processes of the heating and cooling of the atmosphere, it is deemed unnecessary to explain the causes of the change of the seasons, or why a change of conditions is experienced with a change in latitude on the earth's surface.

It has been found that oxygen and nitrogen absorb very little of the solar radiation during its passage downward through the atmosphere, and that most of this function is performed by the water vapor although the dust particles are also a factor. Since the water vapor practically disappears at an elevation of about 6 miles, it follows that the absorption of heat is very slight beyond that distance, and even at elevations of 4 or 5 miles it is small as compared with that at lower altitudes. From the fact that one-half of the atmospheric gases and more than four-fifths of the moisture lie below an elevation of $3\frac{1}{2}$ miles, it becomes evident that much more than one-half of the total absorption of solar heat takes place in these lower air strata.

Fully one-half of the solar radiation is ordinarily absorbed in its passage downward through the atmosphere, and of that which reaches the earth's surface a portion is absorbed while the remainder is reflected and is largely taken up during its outward passage through the moist lower air strata. The heat that is absorbed by the earth's surface is being constantly radiated and supplements that which is directly absorbed by the air. Also heat radiates more rapidly from a dry atmosphere than from a moist one, and thus as the moisture content decreases with increased elevation there is a corresponding increase in the rate of radiation.

In considering the conditions which affect the relative temperatures of the upper and lower air strata, we must admit another important factor which is of a dynamic character. When warm surface air is carried upward by rising currents the pressure upon it decreases steadily by the weight of air that is left below, and according to Boyle's law the gases must expand at such a rate that their density shall be constantly proportional to the pressure that they support. The work of expansion is performed against the force of gravity and consumes heat, thus lowering the temperature steadily at about the rate of 1° for every 270 feet of ascent. Conversely, if air from great altitudes is carried toward the earth the pressure upon it increases constantly and reduces its volume, but in this instance the work is performed on the air by the attraction of gravity, and thus raises its temperature.

By combining all these conditions it may be readily understood that the air strata near the surface are warmest, and that ordinarily the temperature decreases with increase of elevation. However, we sometimes have conditions known as inversions, in which the temperature increases with elevation for a few thousand feet. Also beyond the limits of the moisture content the temperature of the atmospheric gases is believed to be nearly constant at all elevations. The foregoing explanations account for the perpetual snow and ice on the tops of our loftiest mountains.

A water surface reflects a large portion of the heat that reaches it, while another large portion is used in the evaporation of moisture. The comparatively small amount that is absorbed warms the surface but little as it penetrates to a considerable depth. On the contrary, a land surface absorbs heat rapidly, reflects very little, and only a small portion is used in the evaporation of moisture. The portion that is absorbed does not penetrate deeply, and hence a given amount of heat will warm a land surface about four times as much as it will a water surface.

Inasmuch as the heat penetrates the water to a considerable depth, it is retained and radiates back slowly, while on the land it remains near the surface and radiates rapidly. A land surface heats and cools

faster than a water surface, and consequently the temperatures over the continents are subject to greater extremes and more rapid changes than those over the oceans. The difference between the conditions over the land and over the water are not so noticeable in coast districts because of the equalizing effects of the land and sea breezes, but there is a marked contrast between those over the interior of the continents and far out over the oceans.

From the foregoing it can readily be understood how very unequally the atmosphere is heated. The change of the seasons; the different latitudes with the consequent varying angles at which the sun's rays penetrate the atmosphere; the oceans and the continents; the mountains and the valleys; the sand deserts and the verdant fields; the clear skies and the varying cloud formations are all contributing factors to the unequal heating that keeps the atmosphere in continual motion.

VII. Circulation of the Atmosphere.

Cold air is heavier than warm air under corresponding conditions, because heat expands the atmospheric gases and makes them less dense. We can see this principle illustrated in the hot-air balloon which rises because the superheated air in the sack is lighter, volume for volume, than the colder surrounding air, and it is forced upward in the same manner that a cork when released under water is forced to the surface. In general we may assume that the greater the difference in the temperature of adjacent volumes of air, the more energetic will be the movement or action to restore equilibrium, which accounts for the violent local disturbances in the atmosphere.

Bearing in mind that superheated air rises, and at the same time considering the temperature conditions that obtain on various portions of the earth's surface, we may reason out some of the movements that actual observations have proven to exist. In the equatorial belt the superheated air is constantly rising and flowing out on either side toward the poles. The cooler surface air that flows steadily in from either side and displaces the warm rising air constitutes the trade winds, which blow from the northeast in the Northern Hemisphere and from the southeast in the Southern Hemisphere.

The air that rises in the equatorial belt and flows out on either side can not move directly toward the poles on account of the convergence of the meridians. In other words, air can not move from all sides toward a common center, and in much the same manner that water flows around the outer portion of a whirlpool and approaches the center gradually, so the air passes around the earth at intermediate altitudes and forms a cyclonic circulation in each hemisphere that is most marked in the temperate zones. The direction of the circulation is determined by a force arising from the rotation of the earth

upon its axis, which deflects freely, moving particles to the right in the Northern Hemisphere and to the left in the Southern Hemisphere.

Underneath the eastward flow of air in the temperate regions, the unequal heating and the surface configuration break the circulation up into cyclonic and anticyclonic eddies which are shown as highs and lows on the weather maps. The extent to which the surface configuration enters into the formation of highs and lows is problematical, but it is known that the continent of Asia, with its different trend of mountain ranges from those of North America, is relatively free from such disturbances. The highs and lows are very shallow formations, being only about 2 miles in depth and sometimes more than 2,000 miles in diameter, and they are moved from west to east by the friction of the upper easterly air currents. Local disturbances, such as thunderstorms, tornadoes, waterspouts, and squalls, occur within the lows, while thunderstorms are not uncommon within the outer border of the highs.

The weather maps reveal the fact that the wind never blows in a straight line, although locally it appears to do so. All of the atmospheric movements are in whirls or eddies, large or small, the precise character of the whirl depending partly upon its size and partly upon surrounding conditions. All of the lesser disturbances, up to and including the high and low pressure areas shown on the weather maps, have a movement of translation in addition to the whirling or vortex circulation.

The most energetic air movements are tornadoes, which are local disturbances seldom more than 150 or 200 yards in diameter and which become so violent that the largest and strongest buildings are torn into pieces and strewn over their paths. In a tornado the depth is many times the diameter, so that the disturbance has a funnellike formation. In the larger disturbances, such as hurricanes and the large lows the area covered is relatively so great that they become very thin disks. The precise type of circulation must vary in these different formations, although it is cyclonic in each instance. A high may be likened to an inverted low, inasmuch as the circulation is the reverse of that in the low. The small dust whirls that we sometimes see in the street or over plowed fields illustrate the cyclonic principle of atmospheric circulation.

VIII. Atmospheric Pressure.

The pressure of the air is the prime element in the study of all of its movements, and careful measurements of the pressure over large areas enable us to outline the great atmospheric disturbances. The air pressure is merely the combined weight of all the atmospheric

gases, and as previously explained it is equal to a layer of water about 34 feet, or a layer of mercury about 30 inches, in depth at sea level.

The gases press equally in all directions at any given point, and consequently an open vessel, or any substance which the air can freely permeate, sustains no appreciable strain because it stands in the gases in the same manner as does a boat in the water when it is filled and sunk. If an empty boat should be loaded to its capacity and no water allowed to enter it, then the pressure of the water on its sides and bottom would be equal to the combined weight of the boat and the load, and if the framework should not be strong enough to resist such a pressure the boat would collapse. Similarly, if we should take an air-tight tank or barrel at sea level, seal it and exhaust all the air from within, the outer walls would then be subjected to a pressure of approximately 2,000 pounds per square foot. When we exhaust the air from within a rubber bulb, the bulb collapses because it is not rigid enough to withstand the outside pressure.

We do not feel the pressure of the atmosphere under ordinary conditions because air permeates all the tissues of the body. However, if it were possible to exhaust all the air from the body of an ordinary sized man, thus leaving him under the full influence of the outside pressure, he would be crushed by a weight of more than 14 tons.

By reducing, or entirely removing, the air pressure from one direction, it becomes perceptible and measurable from the other directions. A mercurial barometer is an instrument designed to utilize this principle, and in its simplest form it consists of a glass tube about 34 inches in length and sealed at one end. The tube is filled with mercury to exhaust all the air and is then inverted, with the open end resting in a cup of mercury. When the mercury starts to flow out of the tube it leaves a vacuum above it, thus removing all the air pressure from above on the surface of the mercury that is in the tube. Enough mercury will remain in the tube to balance the atmospheric pressure on the exposed surface of the mercury in the cup. To be more exact we should say that the weight of the mercury in the tube balances the pressure on such a portion of the surface of the mercury in the cup as would equal in area a cross section of the glass tube. Thus an increase or decrease in the area of the exposed surface makes no difference in the results.

A barometer may be constructed by using water or other liquids instead of mercury, but since the atmospheric pressure is equal to a layer of water about 34 feet in depth it becomes evident that the glass tube would need to rise more than 34 feet above the surface of the water in the cup. The barometer was invented in 1643 by Torricelli, a pupil of Galileo.

A standard barometer consists of the above-described simple instrument incased in metal for better protection. A scale and vernier are attached near the upper end of the tube to facilitate accurate readings of the height of the mercurial column. An ivory point establishes zero of the column, or the point to which the surface of the mercury in the cup must be adjusted before reading. With these accessories the instrument becomes a fine balance, more sensitive and accurate than an apothecary's scales.

Aneroid barometers are designed for portability and are much less sensitive and accurate than the mercurial instruments. Instead of being true balances, they utilize the principle of the spring scale. The legends "Fair," "Change," "Rain," and "Stormy," often found on the dials, have no significance, and are commonly placed only on popular-priced instruments of medium or inferior quality.

Barometers, of either type, actually weigh the pressure of the atmosphere, and if their indications were expressed in pounds, ounces, drams, and grains instead of giving the height of the mercurial column, or its equivalent pressure, in inches and fractions of inches, the instruments would seem less mysterious to the average mind.

The passage of the great areas of high and low pressure across the country causes the mercury in the barometers to fluctuate slowly but continuously. The change is not so much as is commonly supposed but is very significant. In 40 years of Government weather records in Philadelphia, the highest barometer recorded is 30.96 inches and the lowest is 28.69, thus making an extreme range of 2.27 inches. This indicates a difference in pressure of about 160 pounds per square foot of surface, and is the same change as would be experienced in rising from sea level to an altitude of 2,150 feet. It is unusual for a barometer to change as much as an inch in 24 hours, and such a change indicates an energetic disturbance moving at a rapid rate.

IX. Relation of Air Pressure to Wind Movement.

Barometric gradient is a term used to express increase or decrease of pressure along a horizontal surface between two points, and upon its steepness depends the energy of a storm and the rate of the attendant wind velocities. Thus if a crest of high pressure was over Bismarck, N. Dak., with a barometer reading of 31 inches, and at the same time a center of low pressure was over Philadelphia, with a barometer reading of 29 inches, the barometric gradient between the two places would be said to be very steep. On mapping such conditions the isobars would be close together, the pressure formations would be intense and energetic, and high winds would prevail between the two centers.

As explained in a previous chapter, the air currents flow from regions of high pressure over certain curved lines toward regions of low pressure, and the barometric gradient determines the velocity of the wind. As the air currents approach a center of low pressure their velocity normally increases until they reach a point where the horizontal component is partly overcome by being deflected upward near the center. To understand this, you may observe, when pouring water through a funnel, that it moves faster near the center than it does toward the outer edge. This phenomenon is in accordance with a well known mathematical law.

In West Indian hurricanes the barometric gradients are usually very steep, which accounts for the destructive gales of wind that are developed. The relation of the velocity of the wind to the barometric gradient is sometimes likened to water flowing down an incline, but the illustration is not in all respects a good one.

X. Water Vapor.

Heat breaks water up into its molecules, and imparts to it many of the properties of a gas. In fact, water vapor is commonly defined as being water in a gaseous state. It is different from most gases in that it can change from a gaseous to a solid form, as from vapor to frost, without passing through the liquid state, and conversely, ice and snow may pass directly into water vapor without becoming liquid.

The heat energy that is required in the process of evaporation is rendered latent, or imperceptible by any means, until the vapor is condensed back into visible water particles, when it is freed again as sensible heat. It is therefore easily understood that evaporation from a moist surface has a cooling effect, and the more rapid the evaporation the faster will the heat energy become latent and the greater will be the cooling effect.

We commonly speak of moist and dry air with the implied meaning that the gases of the atmosphere soak up the vapor much as a sponge would take up water, and the matter is probably understood in that light by many; but the fact is that the vapor occupies space practically independent of the other gases. At any given temperature, the same amount of vapor can be diffused through a vacuum as through an equal volume of air at sea-level pressure.

The amount of vapor that can be diffused through a given space is governed almost entirely by the temperature, and the amount of moisture can be practically doubled with each increase of 20° within the ordinary ranges experienced in the free air. Thus by raising the temperature from zero to 80°, the capacity of a given space for moisture is increased almost sixteenfold.

Water vapor is invisible until the space which it occupies is supplied to the limit of its capacity at that temperature, after which any additional moisture becomes visible as steam, fog, or cloud, which are all really identical in formation. A reduction of temperature under such conditions will also cause condensation by reducing the capacity of the space for holding vapor, which is virtually the same as adding vapor beyond the capacity.

If we could look into the boiler of an engine nothing would be visible above the surface of the water which it contained, although the pressure of the vapor might be 150 pounds or more to the square inch. The temperature in the boiler would be very high, and the instant that the vapor escaped from it into the free air it would be condensed by its expansion and sudden cooling and would become visible. When vapor is beginning to condense into visible fog, a rise in temperature will cause it to again become invisible.

Night fog is caused by the radiation of heat from the surface of the ground and from the adjacent air strata until the temperature falls to a point where a portion of the atmospheric vapor condenses. The temperature at which such condensation begins is known as the dew point, and at that time we say that the atmosphere is saturated. Saturation occurs in a dense fog, which is like a cloud at the surface of the earth instead of at a higher elevation as usually seen.

At times there may be present in the atmosphere only one-half or three-fourths of the amount of moisture needed for saturation, and when this amount is considered with relation to the amount necessary for saturation it is termed relative humidity. Thus we may say that the relative humidity is 40 per cent, meaning that two-fifths, or 40 per cent, as much moisture is present as would be needed for saturation at that temperature.

The rate of evaporation from any water or moist surface is mainly controlled by two factors namely, the air movement and the relative humidity. Water vapor exerts a certain pressure that is not produced by the other gases on a water surface, and this pressure has a controlling effect on the rate of evaporation. When saturation occurs the vapor pressure is such that evaporation becomes almost nothing, and at such a time if the air were to become quiescent it is probable that evaporation would cease entirely. Thus during a period of high temperature and light winds the conditions become oppressive if there is much moisture present, or, in other words, if the relative humidity is high, because at such times the perspiration is evaporated from our bodies slowly and we do not experience the cooling effects that accompanied a drier atmosphere or stronger winds, with the rate of evaporation much greater.

The condensation of water vapor into visible particles seems to require some solid substance upon which to collect. Thus you have

noticed the moisture condense on the outside of a pitcher of ice water. The cold pitcher reduces the temperature of the adjacent air below the dew point and the surface of the pitcher forms the solid substance upon which the moisture can collect.

When condensation takes place in the free air the dust particles act as the substance upon which the moisture can collect, and each minute water globule contains a dust mote. This is true whether condensation takes place as fog near the earth's surface or as clouds at high altitudes. Atmosphere entirely free from dust has been artificially cooled far below the dew point without condensation, but upon admitting a little puff of dust-laden air the moisture condensed into fog immediately. The necessary dust particles are carried up into the higher altitudes by the same air currents that carry up the water vapor, and air currents carry dust from the continents across the oceans, thus facilitating the condensation of water vapor in all parts of the globe.

At night in summer time the radiation cools the surfaces of vegetation below the dew point of the adjacent air, and the moisture collects on the leaves in precisely the same manner as it does on a pitcher of ice water. Very little, if any, moisture is seen on the pavements or other solid substances which absorb so much heat during the day that they do not cool below the dew point at night.

When condensation takes place on any surface the temperature of which is below the freezing point, it forms frost instead of dew. Remember that dew does not "fall" according to the common expression, but the moisture collects from the air that comes directly into contact with the cooled surfaces.

XI. Precipitation.

Rain, snow, hail, and sleet are all comprehended in the general term "precipitation," and their differences in character are due to the conditions under which they are formed. Thus, while dew, frost, and low fog are caused principally by the cooling from radiation, the formation of rain, snow, hail, and sleet is due to the process of cooling that ordinarily attends the expansion of rising air currents.

If the dust particles in the rising air are plentiful and the ascent is not too rapid, the moisture will condense on the dust in extremely small globules, which, being very light, will be supported by the rising air and will float along as clouds instead of falling to the earth as a mist. If the ascent should be rapid and the dust particles few, a larger amount of water will collect around each dust mote and the globules will become heavy enough to fall through the rising air currents to the earth. Thus raindrops form mostly in the upper portions of the clouds, where the cooling is greatest and where the dust particles are fewest, and then in falling through the clouds they collect more moisture and increase in size.

If the vertical air currents are intermittent and quite strong, as in a thunderstorm, the raindrops are sometimes carried back and forth through the clouds, accumulating the smaller water globules until they become very large. The condition of the atmosphere between the clouds and the earth with regard to moisture is also a considerable factor in determining the size of the raindrops. When this atmosphere is almost saturated the raindrops may increase in size while passing through it, while conversely a warm dry atmosphere may evaporate the rain before it reaches the earth. It is not an uncommon occurrence on a warm summer afternoon to note rain falling from a cloud and gradually evaporating until it can no longer be followed by the eye.

The difference between rain and snow is similar to that between dew and frost. When condensation in the free air occurs with the temperature below freezing, the vapor passes directly into the form of minute ice crystals without first forming water globules. Hundreds of these ice crystals unite to form a snowflake. When snowflakes are examined under a microscope they are found to form regular six-sided figures in an almost endless variety of geometrical designs. Under ordinary conditions it takes from 8 to 12 inches of snow to equal in moisture 1 inch of water.

The formation of hail has never come under direct observation as has that of dew, fog, frost, rain, and snow, and consequently our knowledge of the process is largely theoretical. The conclusions in this respect are based upon two phenomena. First, true hail occurs only in warm weather and is usually an accompaniment of thunderstorms where strong vertical air currents are present. Second, on cutting a hailstone through the center it is found to be made up of concentric layers of snow and ice.

It is therefore reasoned that the hailstone formation is begun by a raindrop being carried to such an altitude that the expanding air about it is cooled below the freezing point, and therefore the drop is frozen, then falling back into the warmer stratum of cloud and rain, where its cold surface immediately collects a coating of water, only to be carried by another gust of rising air back into the higher altitudes to be frozen. This process is continued by the intermittent gusts of rising air until the hailstone becomes so large that it can no longer be supported aloft, when it falls to the earth. Sometimes several hailstones touch and freeze together, falling to the earth as a large irregular chunk of ice.

During the winter season rain sometimes forms in a stratum of air where the temperature is slightly above freezing and afterwards falls through colder air strata and reaches the earth in the form of frozen rain drops or ice pellets. This form of precipitation is not hail but sleet. Sometimes the raindrops and ice pellets are mixed, with the temperature practically at the freezing point, and if the surface air

temperature is below freezing a coating of ice is formed on every exposed surface.

The processes of condensation and precipitation are on such a stupendous scale in nature, even during the progress of a light shower, that all the artificial forces controllable by man are puny by comparison. The stories sometimes circulated regarding the accomplishments of so-called rainmakers fail to take into account the general atmospheric conditions prevailing at the time. When showers follow the rainmaker's operations and he therefore claims success the weather map almost invariably shows rain over too large an area to have been the result of local agitation, no matter how seemingly violent that agitation may have been. A clear sky, locally, at the beginning of the operation does not argue that the showers which may follow are the result of the rainmaker's efforts.

XII. Weather Forecasting.

You can now begin to apply to the weather map the principles learned in a cursory study of the elements, and by so doing you can begin to anticipate storm movements and developments. Many changes occur in the atmospheric disturbances during their progress across the country, owing to the continual shifting of their relative location with regard to mountains, lakes, the seashore, or to extensive dry plains. It must be remembered that the barometric pressure areas are only formations through which the atmosphere circulates and that they do not carry a given quantity of air with them across the continent.

Weather forecasting consists in watching the storm movements and developments by means of the weather maps, in anticipating the changes that will take place in them, in estimating the expanse of territory that will be covered and the time that given points will be reached, and thereby determining the weather conditions that may reasonably be expected in each locality during the ensuing 36 to 48 hours. A chart, showing average storm tracks and average daily movements in the United States, will be found at the end of this chapter.

About 60 per cent of the areas of low barometer in the United States are first seen over the extreme northwestern portion of the country, and thence they move eastward along the northern border, across the Great Lakes, and finally pass off the north Atlantic coast. From your knowledge of the elements you can now reason out the changes that may be expected to occur within these disturbances during their progress over this northern route.

When a low-pressure area is central over Idaho, for example, you can readily understand that the precipitation within it will ordinarily be light, inasmuch as the air that circulates through it flows in from comparatively dry regions. The air currents from

the Pacific rise rapidly as they flow inland and, cooling by expansion, they are deprived of a large portion of their moisture on the western side of the Cascade range of mountains.

When the center of the disturbance has moved eastward across the Rocky Mountains the rainfall begins to increase in the eastern side of the area, occasioned by the greater quantity of moisture in the atmosphere that flows in from the central valleys and from the western portion of the Lake region. From thence eastward the storm usually increases in energy as it reaches into lower altitudes and moister regions, but ordinarily these disturbances do not cause heavy or excessive precipitation.

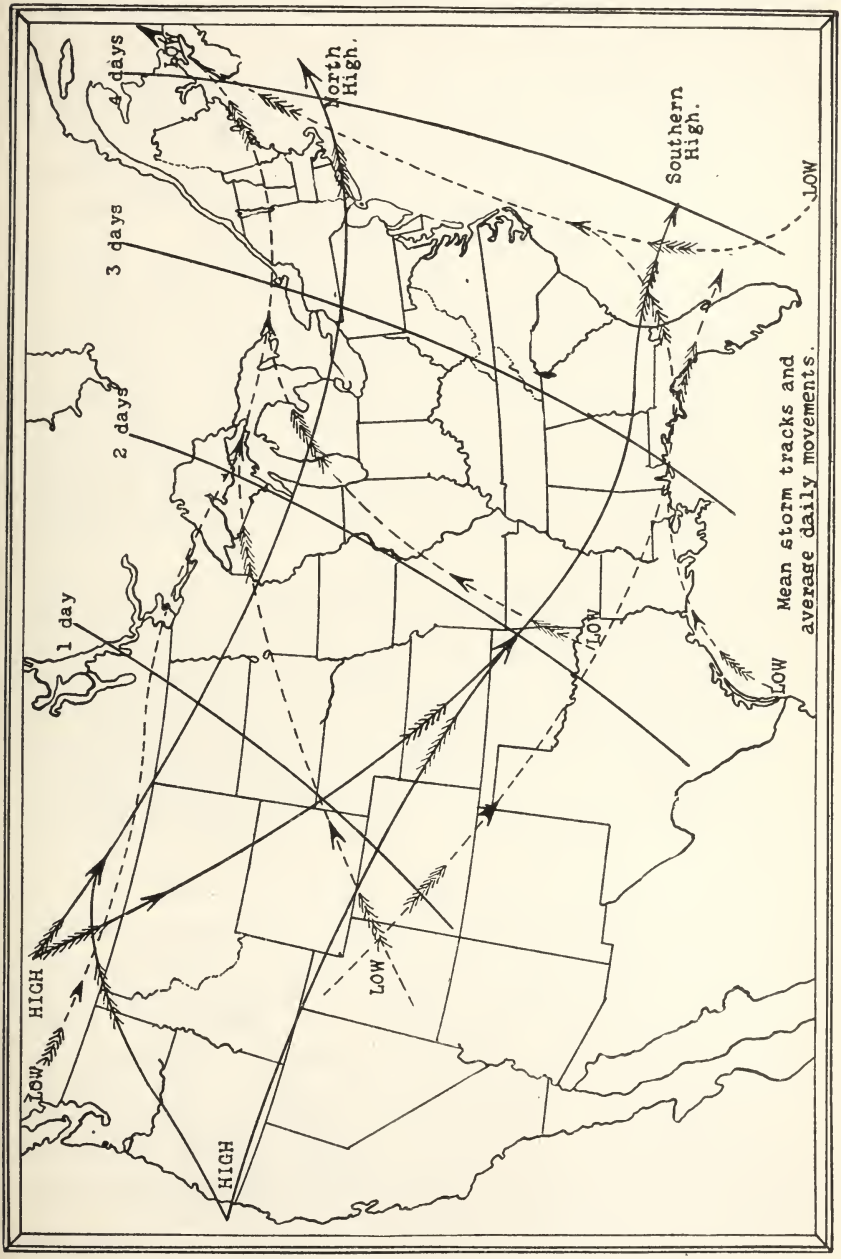
The low-pressure areas that are first seen over the southern plains, and those that move into the Southern States from the Gulf of Mexico, generally drift northeastward and pass off the north Atlantic coast. They are usually more intense and energetic than the disturbances that cross the country along the northern border because they move through moister and warmer regions.

Now conceive a well-developed storm to be central over northern Texas and drifting toward the New England States. During the entire time that it is crossing the great central valleys it is drawing warm air currents from the Gulf of Mexico heavily laden with moisture. The rainfall attending such storms is generally heavy, and their passage sometimes breaks up severe droughts in the great corn and wheat belts. As these storms move farther northeastward they pass between the Great Lakes and the Atlantic coast, and the decreasing supply of moisture from the Gulf is largely counteracted from these other sources and heavy rains may and generally do continue.

The storms that move up from the Tropics to the south Atlantic or Gulf coasts of the United States during the late summer or early autumn are termed "hurricanes." They are usually smaller in area than the storms which form on the continent, but are more intense and energetic. When first seen in the Tropics, they have a tendency to move slowly northwestward, and to continue in that direction until they reach the latitude of the Gulf coast, when they recurve to the northeast unless prevented from doing so by an area of high barometric pressure. On recurving they usually increase their rate of movement and sometimes sweep over our entire Atlantic coast in less than 48 hours.

When a hurricane makes its appearance in southern waters it is necessary to receive frequent reports from all observation points in its vicinity and watch its movements very closely in order to issue warnings ahead of it. Before the storm-warning system of the United States Weather Bureau was developed to its present high degree of efficiency these storms used to strew the Atlantic and Gulf coasts with the wrecks of vessels. Although the number of vessels

engaged in coastwise trade has increased considerably, the number of wrecks is but a small fraction of those of former times.



During the last few years the Weather Bureau has received reports by wireless telegraph from several cooperating vessels and its survey of the tropical regions has been much more complete than formerly.

XIII. Weather Forecasting (continued).

Cold waves usually accompany energetic areas of high barometric pressure following those of low pressure. They are confined principally to the winter months, when temperature changes are most sudden and pronounced. If a rapid fall in temperature occurs in summer it is usually from a point much above the normal to a point as much below the normal without injurious conditions at any time, but in winter a fall from the freezing point to a temperature near zero would do much damage unless ample warnings were issued so as to allow the protection of perishable products.

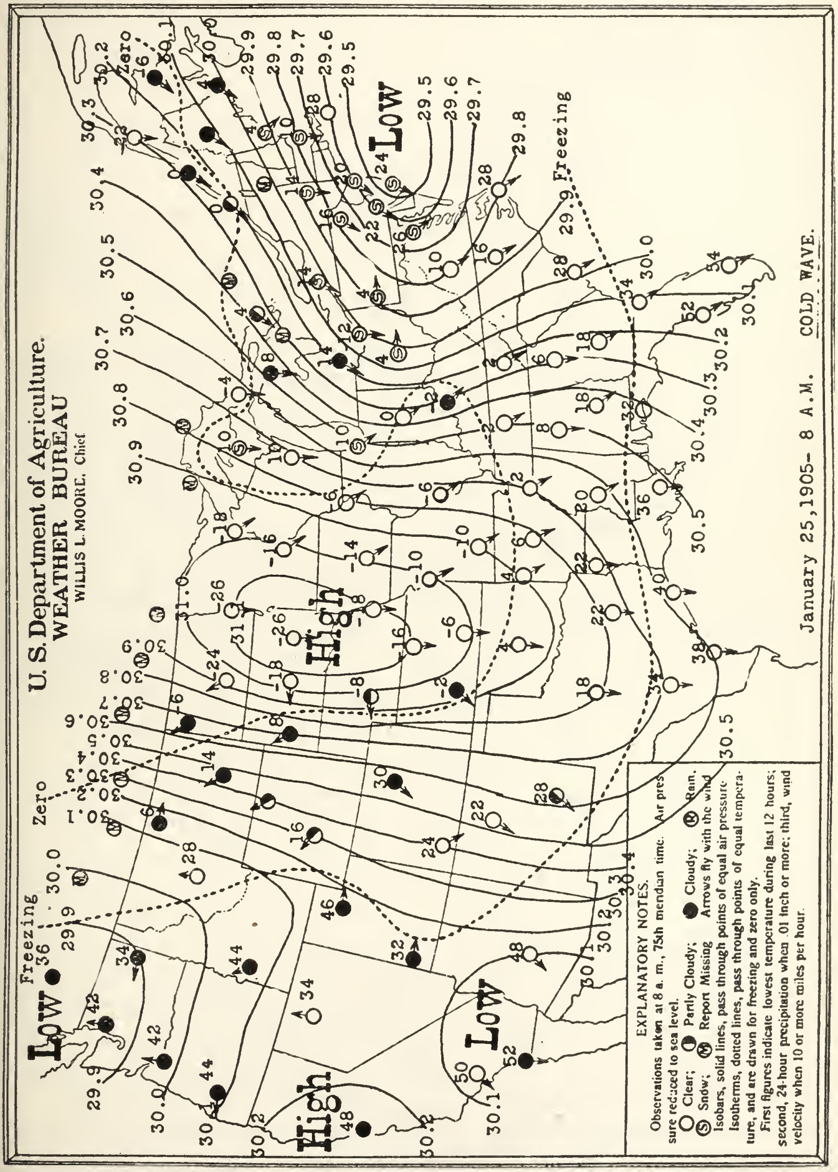
You have learned that the areas of high barometric pressure make their first appearance in the far northwest, usually over the northern Rocky Mountain plateau, and that they move either eastward across the Northern States or else southeastward to the lower Mississippi Valley, and then recurve to the eastward or northeastward. You have also learned that in these areas the air settles down cool and dry from the higher altitudes, or, more correctly speaking, the air settles down in the central portion of the area, while away from the central portion all the lower air currents have a slight deflection downward.

During the winter season, if a high pressure area appears in the far northwest, with a low area over the Southern States, the low area will usually move eastward and northeastward, while the high area, with its attendant low temperatures, will sweep southward to the Gulf coast. Should there be no well-defined area of low pressure over the Southern States, the high area would be more apt to pass eastward over the northerly route. A high-pressure area that is not preceded by a low will not cause so great a fall in temperature in proportion to its intensity as one that is thus preceded.

The high-pressure areas that move from the Northwest into the Southern States usually decrease in energy on recurving to the eastward or northeastward, and so reach the Atlantic States in a modified form that seldom causes a marked fall in temperature. When cold waves occur in the North Atlantic and New England States they follow closely upon the passage of a center of low pressure, the high-pressure area generally moving eastward or southeastward from the upper Lake region. Under certain conditions a cold wave may occur at the rear of a center of low pressure, with no well-defined high-pressure area following it, but in any event an increase in barometric pressure accompanies every cold wave.

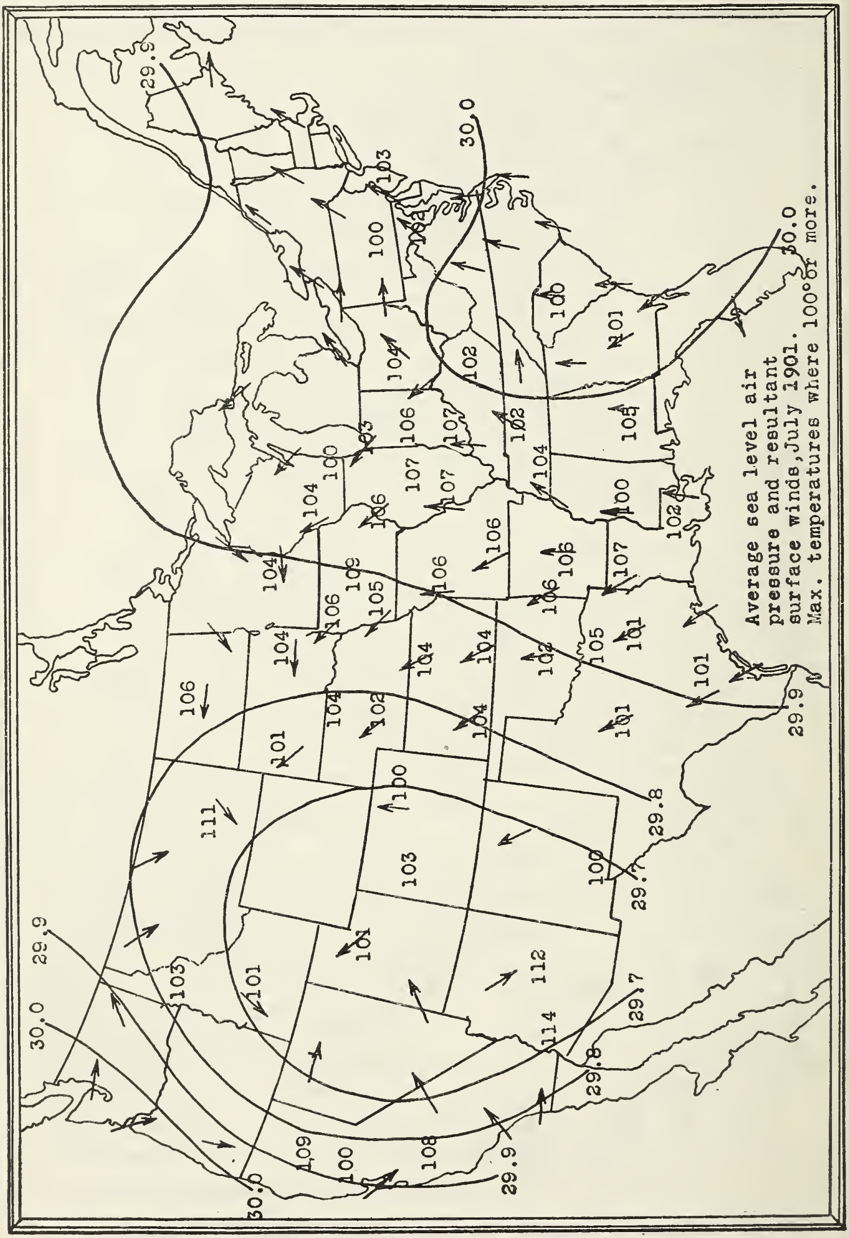
Mention has been made of the tendency of the air currents to flow from a crest of high pressure toward a center of low pressure, and it is therefore plain that when a cold area of high pressure is following a low from the Northwest the temperature will begin to fall at any

given place in its track as soon as the center of the low has passed eastward far enough to bring that place within the flow of air between the two centers.



Excessive heat is caused by barometric pressure gradients being practically the reverse of those in a cold wave, the high pressure being in the Southeast and the low pressure in the Northwest. During the summer season an area of only moderately high barometric

pressure will sometimes stagnate over the South Atlantic States or just off the coast, while a low moves into the upper Mississippi Valley and the upper Lake region. Under such conditions the air cur-



Average sea level air pressure and resultant surface winds, July 1901. Max. temperatures where 100° or more.

rents that flow from the central portion of the high area toward the low move along the surface and, steadily increasing in temperature, they gather up moisture over their course and cause abnormally

warm and humid conditions in the Ohio Basin and in the Middle and North Atlantic States. If the areas are large, with the crest of high pressure off the south Atlantic coast and the center of the low in the far Northwest, the abnormally high temperatures will cover all the great central valleys.

The month of July, 1901, marked the most intense period of abnormal heat from the Atlantic coast westward to the Rocky Mountains that has been recorded in the United States. The average barometric pressure for the month serves to illustrate the conditions that caused the intense heat much better than a map for any specific date, and a chart showing the average pressure for that period has been taken from the Monthly Weather Review and adapted to this purpose.

XIV. Weather Forecasting (continued).

In our Northern States much the greater portion of the rainfall occurs on the eastern and southern sides of low-pressure areas. The heaviest rains in the Southern States are usually caused by low-pressure areas moving in from the Gulf, but rain often occurs when an area of high pressure moves down from the north, the cool descending air currents appearing to run under the moist lower air strata which are raised, cooled by expansion, and a portion of their moisture condensed and precipitated.

The areas of high and low barometric pressure are more energetic, excepting the West India hurricanes, and move across the country at a more rapid rate during the winter than during the summer season. The rate of movement of a storm area across the country should not be confused with the wind velocities within its boundaries, for sometimes a storm that is moving quite rapidly will be suddenly checked and will increase in energy as a consequence, thus developing higher wind velocities than when its movement of translation was greater. The West Indian hurricanes travel very slowly so long as they follow the westerly course, but the wind velocities generated within them are usually destructive.

The rate of movement of storm areas is seldom steady and uniform for any considerable length of time, but the average rate is about 37 miles per hour in winter and 22 miles per hour in summer. They travel faster across the Northern States than they do in the southern portion of the country.

High-pressure areas have a greater tendency to turn southward while crossing the great central valleys in the winter than they have during the summer. The larger and better formed all atmospheric disturbances are, the easier it becomes to anticipate their movements and developments and thereby to forecast ahead of them. It is when a map shows several partly developed areas, or when their movements become sluggish, that forecasting becomes most difficult.

So long as a disturbance keeps moving the forecaster has a basis for his calculations, but when it becomes stationary he has no means of determining when it will start to move again.

During midsummer when the pressure formations are least energetic there is a tendency for conditions to become localized, and we have showers instead of general rains. When conditions indicate showers a forecast must be made for them, and while they may cover much the greater portion of the territory for which they are forecast, still there will be many places where no rain will occur and where the forecaster will be blamed for missing his calculations.

When conditions are such as to indicate only a few widely scattered showers, the better policy will be to forecast fair weather, as that condition will no doubt prevail over three-fourths of the territory covered by the forecast. In those scattered localities where showers occur the forecaster will again be blamed for an unpardonable blunder.

In estimating the resultants of storm movements and developments it is necessary for the forecaster to estimate the intensity and effect of a great many forces, and to perform the work with great rapidity. He must be continually on the alert if he would make a high percentage of successes in his work.

XV. Forecasting from Local Indications.

The ability of mariners to forecast weather changes from local observation is proverbial. This is not because the signs are so much more pronounced over the ocean than over the land, but is primarily because the mariner has no other source of information and must learn to interpret their significance. On land a heavy storm is not so often a matter of life or death, and consequently while most people recognize a few weather signs they rarely follow them out in a systematic manner to determine their reliability.

About three-fourths of the population of our country can be readily reached with the information disseminated by the United States Weather Bureau by means of its publications, by the daily papers, and by telegraph and telephone. This advice being more reliable than local signs, has practically supplanted them in all the districts covered, and many lines of business and many social functions are planned and conducted accordingly.

Weather changes are not usually definitely heralded by local signs for a period longer than 12 hours in advance, while many local storms give scarcely an hour's notice of their coming. Very few indications apply with equal force to all parts of the country. Conditions along the Pacific coast differ materially from those along the Atlantic coast, the Gulf coast, or the interior of the continent, and in the interior there is a great difference between conditions in the Rocky

Mountain region and the central valleys or the Great Lakes. Many signs which might be considered reliable in the Ohio Valley would be valueless in the drier districts of the far Southwest.

In order that one may formulate a series of signs that will be distinctly applicable to the locality in which he lives he should proceed in a careful and systematic manner to record and correlate his observations. Weather proverbs will not be found to be generally applicable, and only those which when analyzed are found to be based on scientific fact will be worth considering.

Signs pertaining to the condition of the atmosphere, the appearance of the sky, the character and movements of the clouds, and the direction and force of the winds are, generally speaking, all that are worth testing out for one's particular locality.

Proverbs regarding the actions of birds and animals are usually of little value. Marked changes in the atmospheric conditions are responsible for their peculiar antics, and these same changes are generally preceded by reliable signs, if one learns to observe and interpret them.

Sayings which pertain to the moon and the planets are entirely foreign to the subject, and those which apply to forecasts for coming seasons are wholly without foundation. Peculiar growths and developments in vegetation are the result of weather conditions that have passed and have no connection with those to come. The character of the muskrat's house or the beaver's dam is the direct result of the stage of the water at the time the structures were made.

By mapping the entire Northern Hemisphere the Weather Bureau is enabled to forecast general conditions for a week or 10 days in advance with a creditable degree of accuracy, but at the present time there is nothing known which justifies any person in venturing forecasts for longer periods. Thus, the person who would learn to forecast from local observation will do well to confine his efforts to the detection of weather changes a few hours in advance. It is reasonable to expect a continuation of observed conditions at any time until there are indications of a decided change.

Inasmuch as the barometric pressure is the main feature of the weather map, and is of as much importance to the forecaster as all of the other information combined, it is equally as essential that the local observer should be equipped with some means by which to detect changes in atmospheric pressure. The pressure changes in connection with the wind direction will give him the key to the situation. There are certain wind-barometer indications that are applicable to all localities in our country, and the following statements are published on all Weather Bureau daily weather maps:

When the wind sets in from points between south and southeast and the barometer falls steadily, a storm is approaching from the west or northwest, and its center will

pass near or north of the observer within 12 to 24 hours, with wind shifting to northwest by way of south and southwest. When the wind sets in from points between east and northeast and the barometer falls steadily, a storm is approaching from the south or southwest, and its center will pass near or to the south or east of the observer within 12 to 24 hours, with wind shifting to northwest by way of north. The rapidity of the storm's approach and its intensity will be indicated by the rate and the amount of the fall in the barometer.

On account of its portability and ease of handling, an aneroid barometer is best suited to the needs of the local observer, and a reliable instrument can be purchased for $10 to $15. The legends, if any, on the face of the instrument should be entirely disregarded, remembering that even if at times they should seem to be applicable to a given locality, a change in altitude of a thousand feet would throw them to a decidedly different relative position on the scale.

The brass pointer should be set over the indicating hand on the dial of the instrument morning and evening and the change in atmospheric pressure noted for each 12-hour period. The barometer should be read and the wind direction and force noted when precipitation begins and again when it ends. The character and movements of the clouds should always be observed, as they are the only indicators of the conditions of the atmosphere at higher altitudes.

A series of such observations, when compared and classified, will soon reveal certain well-defined relations that will enable the observer to begin a list of reliable local signs. The list will increase with the period of observation, and established rules will be modified by noting the most common exceptions. Some signs which are reliable for one season of the year will need to be materially changed in order to apply to the conditions of a different time of the year. When a local sign has been thoroughly tested and found to be reliable in a large percentage of cases the observer should then record it permanently for the benefit of future generations in that locality. Each well-established rule will be of incalculable value to that community in times to come.

The observer should remember that all weather changes are the results of physical conditions occasioned by the unequal heating of the atmosphere and modified by the locality and the character of the surrounding territory. Everything savoring of astrology, of superstition, or of the mysterious in general should be entirely rejected, and he should proceed with his work on a purely physical and scientific basis.

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